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INTEGRATION OF POLAR CLASSES
AND ARCTIC ICE REGIME SHIPPING SYSTEM

FINAL REPORT

March, 2005

Submitted to:

NRCC

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BMT FTL DOCUMENT QUALITY CONTROL DATA SHEET

PROPOSAL/REPORT: Integration of Polar Classes and Arctic Ice Regime Shipping System

DATE: March, 2005

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1. THE POLAR CLASS INITIATIVE AND ITS CURRENT STATUS

The new International Maritime Organization (IMO) system of Guidelines for Arctic Shipping incorporates a set of Polar Classes, PC 1-7, which are also the basis for the International Association of Classification Societies (IACS) Unified Requirements for Polar Class Ships.

Both the IMO and IACS systems arise from the Ice Class Rules Harmonization initiative, which was raised through IMO in the early 1990s. Following early proposals from Russia and Germany, a working group was established under IMO's Design and Equipment (DE) Subcommittee to explore how the multitude of national and class rules and requirements could be 'harmonized'; or consolidated. Part way through this process, it was agreed that for hull construction and machinery IMO should establish broad goals, while IACS would establish detailed requirements. In other areas, such as lifesaving, pollution prevention, etc, the IMO approach would be more prescriptive, as classification societies do not typically address these issues in such detail.

IMO adopted the Guidelines in 2001, initially only for operations in Arctic waters. Currently there is a move to establish identical (or very similar) guidelines for the Antarctic, which was initially excluded due to the peculiarities of the Antarctic Treaty regime. Finalization of the IACS Unified Requirements has taken longer, largely due to pragmatic issues of aligning them with the Baltic Ice Classes established under the Finnish/Swedish Boards of Winter Navigation. The Baltic Rules have been the de facto standard for most of the world's ice class ships, and so the alignment of the two systems has been important both to the Baltic administrations and to many shipowners and operators. Agreement has been reached on the hull structure requirements, but the machinery requirements – in particular propeller strengthening – are still in the final stages of development.

Canada, under the leadership of Transport Canada Marine Safety branch (TCMS) has taken a leadership role in the Harmonization initiative as a whole. It has ensured that Canadian knowledge and experience has been taken into consideration in all areas of the IMO and IACS work. Canada's objective has been to ensure that future Polar Class ships can be approved for operation in Canadian Arctic waters with as little administrative effort as possible, and that their actual operation is made as safe as possible by applying appropriate limits and other measures.

An important element of safe operation in Canadian Arctic Waters is the Arctic Ice Regime Shipping System (AIRSS); which matches ship capabilities to actual ice conditions. The objectives of the current study have been to identify key issues involved in incorporating the IMO/IACS Polar Classes into AIRSS, and to develop specific proposals as to how this may be accomplished.

2. DESCRIPTION OF POLAR CLASS CAPABILITIES

2.1 General

The descriptions of the Polar Classes are common to the IMO¹ and IACS² documentation and are provided in Table 2.1 below.

Table 2.1: Polar Class Descriptions

| Polar Class | Ice Description (based on WMO Sea Ice Nomenclature) |
|--------------------|---|
| PC 1 | Year-round operation in all Polar waters |
| PC 2 | Year-round operation in moderate multi-year ice conditions |
| PC 3 | Year-round operation in second-year ice which may include multi-year ice inclusions. |
| PC 4 | Year-round operation in thick first-year ice which may include old ice inclusions |
| PC 5 | Year-round operation in medium first-year ice which may include old ice inclusions |
| PC 6 | Summer/autumn operation in medium first-year ice which may include old ice inclusions |
| PC 7 | Summer/autumn operation in thin first-year ice which may include old ice inclusions |

The definitions have been left very generic quite deliberately (and after considerable debate), as ships of any of the classes may operate safely in a wide range of actual conditions, depending on season and area. In addition, national administrations and other interested parties may impose operational limitations for other reasons, and it is inappropriate for general documents to attempt to offer guidance for all possible circumstances.

2.2 Lower Bound Capability

As the IMO/IACS approach was being developed, there was considerable debate over the appropriate minimum level of capability for a Polar Class ship. A strong body of opinion felt that the least capable Polar Class should be as or more capable in all respects than a Baltic class ship. However, it was noted that many experienced polar operators make extensive use of Baltic class ships, though often with some upgrades to the level or extent of hull strengthening. In the Canadian Arctic, and in the Antarctic, many of the ships that operate regularly have Baltic 1A or 1AS class (Type B and A respectively under the

¹ Guidelines for Ships Operating in Arctic Ice-Covered Waters, MSC/Circ.1056, 2002

² IACS draft UR I1, 2004

Canadian Arctic Shipping Pollution Prevention Regulations, ASPPR). It was, therefore, agreed that the lowest Polar Class should have general levels of strengthening roughly comparable to Baltic 1A, with the intention that a Polar 7 should automatically have sufficient structure to meet all the Baltic requirements. Extensive discussions were held with the Baltic administrations to agree on how this could be accomplished and demonstrated. The final selection of Class Factors (see below) ensures that a Polar 7 meets or exceeds all Baltic 1A structural requirements, and a Polar 6 does the same for Baltic 1AS.

It should be noted that this does not imply that ships with lesser capability (Baltic 1B, etc, and other similar classes) would be prohibited from Polar voyages. The IMO Guidelines make it clear that even ‘open water’ ships are expected to access polar waters, subject to seasonal and environmental limitations. Equally, it does not imply that no credit will be given for levels of ice capability between open water and the lowest Polar Class. This type of decision has been left to national administrations and their systems of navigational control. In international waters, Flag States (or insurers) may also recommend or require differentiated operational restrictions.

2.3 Upper Bound Capability

As the outline descriptions in Table 2.1 show, the intent of the PC 1 classification is to offer a level of capability analogous to that provided by an unrestricted open water class notation. It defines a ship which can operate year round in all polar waters, subject to due caution on the part of the master. This caution implies (for example) limiting speed in certain conditions, avoiding aggressive manoeuvres, avoiding impacts with obvious glacial ice features, etc.

2.4 Number and Relationship of Classes

With the lower and upper capability bounds set, it was necessary to consider how many intermediate classes are needed to give the desired flexibility to operators. The total of seven classes selected can be compared with the numbers used in existing systems to cover roughly the same capability range. Under the Canadian ASPPR 95 Equivalent Standards, there are six (from Type B/Baltic 1A to CAC 1), and under the latest Russian Register Rules there are six to seven (6-7) (from LU3/4 to LU9). A similar number of classes are available under most of the other major Classification Society Rules. In some cases, there are overlaps between general ice and Baltic classes which make it difficult to quote a single number. It was decided relatively early in the Harmonization process that a seven class system would be adopted, subject to subsequent technical justification. No compelling reasons were found to change this selection.

Since there are no clear physical boundaries between the Polar Classes, a rational approach to delineating them is to provide incremental increases in capability that are meaningfully large, without becoming excessively costly. Too large an increase in structural requirements between classes creates potentially large cost increases for small increments in season length or operational flexibility. Too small a change adds to the complexity of the system (by adding classes). If the change in capability is within the

uncertainty limits of the methodology, then the selection of an appropriate class becomes more difficult.

There was reasonable agreement within the IACS group, based on the available operational data, on the necessary spread of class capabilities from bottom to top. These equated to (in the order of) a 250% increase in plating thickness and a 700% increase in framing requirement (shear and modulus) in the bow area (plate strength increases as the square of thickness, frame strength linearly with shear area or modulus). If these increases were to be achieved smoothly over a set of seven classes, plate thickness would increase in increments of approximately 14% and framing by 32% between one class and the next, for the artificial case of constant frame spacing and span, identical hull form, etc.

Approximately these changes in requirements between class were achieved by selection of the various class factors that are used in the URs to define structural requirements. All of the class factors are shown in Table 2.2. The Crushing Failure Class Factor (CF_C) relates most directly to ice load, and thus to scantlings. The capability increments between the three highest classes have deliberately been made somewhat larger than the others, due to the greater uncertainties in their loads.

Table 2.2: Class Factors³

| Polar Class | Crushing Failure Class Factor (CF_C) | Flexural Failure Class Factor (CF_F) | Load Patch Dimensions Class Factor (CF_D) | Displacement Class Factor (CF_{DIS}) | Longitudinal Strength Class Factor (CF_L) |
|--------------------|--|--|---|--|---|
| PC1 | 17.69 | 68.60 | 2.01 | 250 | 7.46 |
| PC2 | 9.89 | 46.80 | 1.75 | 210 | 5.46 |
| PC3 | 6.06 | 21.17 | 1.53 | 180 | 4.17 |
| PC4 | 4.50 | 13.48 | 1.42 | 130 | 3.15 |
| PC5 | 3.10 | 9.00 | 1.31 | 70 | 2.50 |
| PC6 | 2.40 | 5.49 | 1.17 | 40 | 2.37 |
| PC7 | 1.80 | 4.06 | 1.11 | 22 | 1.81 |

All ships of the same ice class are assumed to have the same operational limits, though in practice small vessels are unlikely to be built with the highest ice classes.

³ IACS draft UR I2, 2004

3. TREATMENT OF EXISTING SHIPS

3.1 Commercial Vessels

There is no single and simple way to assign existing ice class ships a new Polar Class. Compared with other ice class rules (polar and Baltic) the hull areas required to be strengthened differ. Polar Class structural design philosophy leads to framing that is stronger relative to plating than is typical of previous classification systems. This leads to higher ultimate strength for the same overall steelweight.

In particular, in comparing the Polar and Baltic classes, the following general trends need to be appreciated:

- The Polar Class ship will require somewhat more coverage of the forebody ice belt than the Baltic ‘equivalent’ (PC 6/7 c.f. 1AS/1A);
- The Polar Class ship will have similar plate thickness but significantly heavier framing than the Baltic equivalent, particularly for transversely framed structure;
- The steel grades in the Polar Class ship ice belt are required to have better fracture properties than the Baltic equivalent (though many Baltic class ships also use ‘good’ steel).

The second point is illustrated by Figures 3.1 and 3.2, drawn from unpublished work conducted to support the finalization of the Polar/Baltic rules equivalency debate. These curves are based on nominal designs and assume that all vessels have precisely the minimum scantlings permitted under the two rule systems.

In consequence, in most ice interaction scenarios a Polar Class ship is somewhat less likely to sustain damage than the Baltic ‘equivalent’, and if damage is sustained, it is likely to be less severe. However, this assumes that in both cases the ships have been built precisely to rule requirements. In practice, this is not always the case. Certain owners (Fednav being a good example), when building vessels for possible Arctic operation, have specified strengthening over the minimum requirement for the notional ice class. More frequently, vessels are built with wastage margins above the minimum rule requirement; and/or incorporate stiffeners (or less frequently plating) that are larger than ice minima due to other design or fabrication criteria.

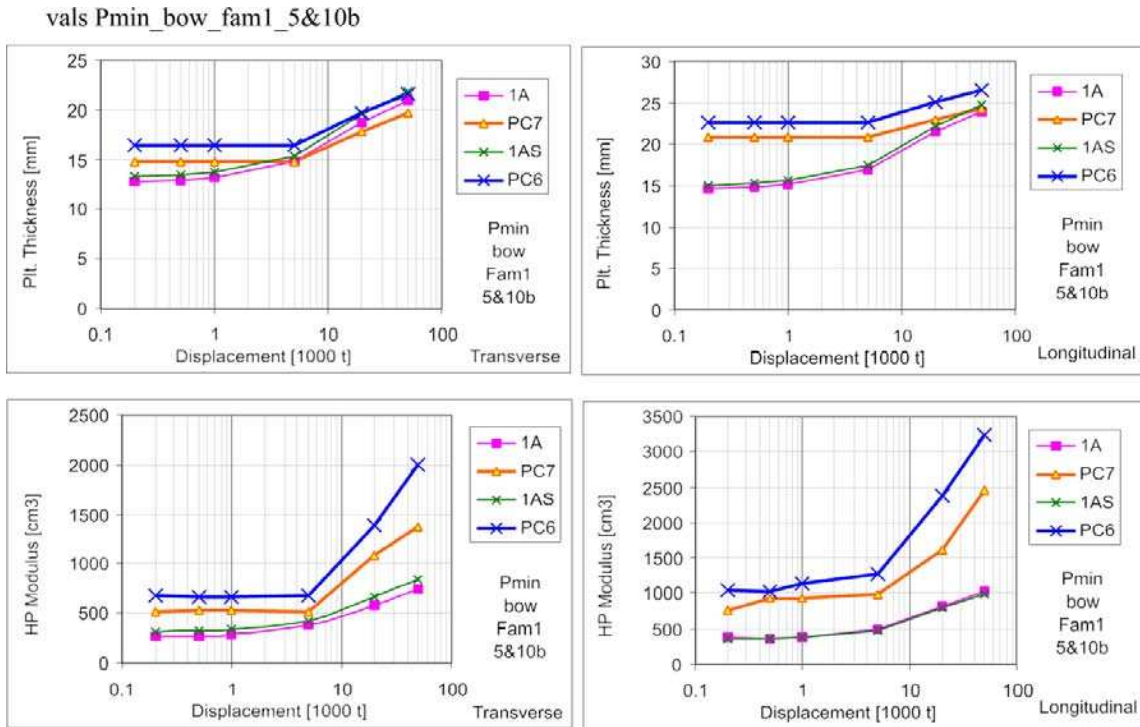


Figure 3.1: Bow Area Scantling Comparisons; Polar/Baltic

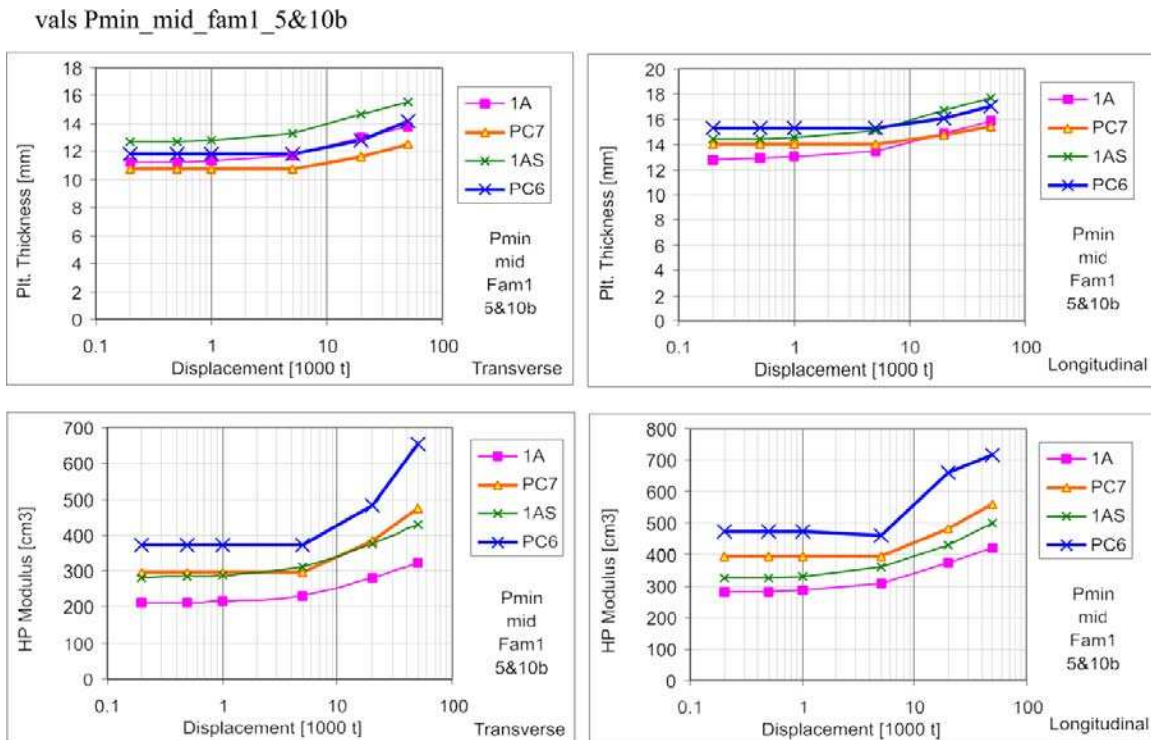


Figure 3.2: Midbody Area Scantling Comparisons; Polar/Baltic

In consequence, a number of existing Baltic 1A and 1AS vessels may have sufficient strengthening to qualify as PC 7 and PC 6 respectively; but this is very difficult to determine without detailed knowledge of the specific design. Some indicators are:

- age: pre-1976 Baltic vessels are weaker than new designs;
- size: larger Baltic vessels are somewhat more likely to meet Polar Class requirements than are transversely framed vessels;
- framing: longitudinally framed Baltic vessels are more likely to meet Polar Class requirements than are transversely framed vessels.

For the purpose of aligning PC/Baltic operating limits under the Arctic Ice Regime Shipping System (AIRSS), it can be assumed that on average a new PC 7 vessel will be as safe as an existing Baltic 1AS, and a PC 6 will be safer. This takes broad account of the differences in scantlings, hull areas, and steel grades between the rule sets in interpreting operational data collected under AIRSS (see Section 4). It should not be considered as setting an equivalency relationship either for specific ships or for ship classes when moving from Baltic to Polar classification.

Operators of certain existing Baltic class ships built with additional strengthening features (such as the Federal Franklin and Baffin) may wish to have their vessels reclassified to the higher PC designation to take advantage of additional operational flexibility (see Section 5). When shipowners invest in new tonnage intended for both Arctic and Baltic use, it is anticipated that the majority will adopt the Polar requirements for operability and risk reduction reasons.

3.2 Icebreakers

Canadian Coast Guard icebreakers have not, in general, been designed directly to any ice class; one exception being the Type 1100 vessels ('Sir Wilfrid Laurier' and sisters). The 1100 class were designed fairly precisely to ASPPR 72 as Arctic Class (AC) 2. They have tended to suffer damage in Arctic operations, especially immediately aft of the heavier bow area and in the unstrengthened bottom. As a result, the planned life extension of the Laurier includes structural upgrades in these areas, and PC 5 requirements have been used as the design base for this.

Table 3.1 illustrates some analyses that have been undertaken of Canadian (and other) icebreakers against the Polar Rules, comparing plating and frame scantlings to the requirements of each Polar Class.

Table 3.1: Icebreaker Scantling Comparisons

| Case Frame Number Case Frame Reference As-Built Ice Class Hull Region | | FrameNum FrameRef IceClass HA | 14 Oden Polar-20 Bow | 16 Louis St. L 100A Bow | 29 Oden Polar-20 Midbody | 31 Louis St. L 100A Midbody | 34 Terry Fox/Kalvik Arctic Class 4 Bow | 35 MV Arctic Arctic Class 3 Bow | 36 Terry Fox/Kalvik Arctic Class 4 Midbody | 37 MV Arctic Arctic Class 3 Midbody |
|--|-----|--|-------------------------------|----------------------------------|-----------------------------------|--------------------------------------|---|--|---|--|
| PLATE THICKNESS | PC1 | | 87.45% | 114.89% | 81.13% | 135.41% | 128.80% | 113.24% | 119.33% | 92.59% |
| | PC2 | | 110.84% | 140.76% | 106.32% | 175.14% | 157.81% | 138.74% | 155.33% | 119.39% |
| | PC3 | | 136.63% | 169.37% | 142.12% | 231.95% | 189.88% | 166.95% | 206.63% | 157.77% |
| | PC4 | | 155.52% | 189.57% | 161.49% | 261.88% | 212.53% | 186.86% | 234.03% | 177.86% |
| | PC5 | | 179.72% | 213.44% | 195.21% | 313.49% | 239.29% | 210.39% | 242.58% | 212.41% |
| | PC6 | | 206.90% | 246.11% | 236.78% | 380.56% | 275.91% | 242.58% | 341.58% | 257.92% |
| | PC7 | | 231.94% | 272.00% | 264.96% | 423.67% | 306.46% | 268.10% | 381.23% | 295.23% |
| SHEAR AREA | PC1 | | 98.63% | 64.20% | 75.50% | 55.96% | 101.58% | 132.03% | 72.45% | 84.45% |
| | PC2 | | 151.34% | 96.36% | 122.58% | 98.75% | 152.48% | 198.18% | 113.51% | 136.62% |
| | PC3 | | 221.29% | 139.52% | 207.05% | 179.33% | 220.76% | 286.93% | 175.99% | 216.02% |
| | PC4 | | 280.63% | 174.77% | 254.72% | 233.92% | 276.55% | 359.44% | 211.55% | 261.39% |
| | PC5 | | 346.69% | 221.55% | 334.33% | 346.61% | 350.41% | 455.65% | 275.98% | 343.66% |
| | PC6 | | 421.90% | 294.54% | 436.49% | 509.35% | 459.63% | 605.75% | 361.32% | 452.47% |
| | PC7 | | 494.86% | 359.76% | 510.35% | 627.81% | 557.03% | 739.89% | 420.79% | 557.28% |
| SECTION MODULUS | PC1 | | 95.02% | 57.90% | 63.74% | 47.64% | 111.63% | 145.01% | 64.63% | 78.22% |
| | PC2 | | 180.80% | 101.57% | 132.05% | 102.12% | 195.94% | 252.58% | 127.32% | 159.77% |
| | PC3 | | 319.95% | 172.02% | 290.29% | 241.46% | 332.17% | 422.54% | 247.62% | 318.79% |
| | PC4 | | 457.14% | 239.78% | 396.56% | 359.62% | 463.41% | 582.16% | 327.49% | 425.04% |
| | PC5 | | 628.78% | 342.23% | 597.84% | 648.34% | 660.97% | 822.95% | 490.58% | 642.51% |
| | PC6 | | 845.67% | 524.58% | 894.19% | 1155.02% | 993.77% | 1260.69% | 739.17% | 974.16% |
| | PC7 | | 1075.76% | 708.15% | 1132.14% | 1580.65% | 1327.26% | 1701.84% | 931.91% | 1334.03% |

The Terry Fox is nominally ASPPR 72 AC 4, but is actually overstrength and has more extensive hull strengthening areas. The new bow of the Louis S. St. Laurent was designed to ASPPR Equivalent Standards CAC 3, but the old hull is quite different. The scantlings of the Henry Larsen are similar to those of the Terry Fox; and in a notional AC 4 strengthening range. The earlier ‘R’ class scantlings are empirical, incorporating (unsuccessful) experience with the original Louis. In the development of the IACS URs, several of these vessels were tested selectively against the draft requirements. The Terry Fox is at PC 1 level in the bow, and PC 2 in the midbody. The Louis is a PC 2 in both areas. Neither the Larsen nor the ‘R’ class has been analyzed against the URs, but it is expected that the Larsen bow and midbody would qualify as a PC 2 and the R class as PC 3. However, as there are believed to be relative weaknesses in other areas, it is considered that all these ships would need to be assigned a Polar Class one or two levels below the nominal capabilities of the bow and midbody, i.e., the Terry Fox, Louis and Larsen could be considered PC 3 and the R Class PC 4.

The M.V. Arctic is another hybrid, which has a very strong bow and midbody but weaknesses in other areas – the stern is an unmodified ASPPR 72 AC 2. In order to operate under AIRSS, she has been assigned unique ice multipliers (though these are essentially those for CAC 4). As a Polar Class vessel, the M.V. Arctic might be considered as a PC 4; again balancing the high strength of bow and midbody ice belt against the much lower strength of her other hull areas.

4. CANADIAN NAVIGATIONAL SAFETY EXPERIENCE (ICE REGIMES)

4.1 General

Under the ASPPR, vessels are permitted to access Canadian Arctic waters under the Zone/Date system (an approximate historical predictor of the severity of ice conditions) and under the Arctic Ice Regime Shipping System (AIRSS). Type ships (up to Baltic 1AS) and older Arctic Class (AC) vessels can use both options. Newer Arctic Category vessels (CAC) can only use AIRSS; however, no ships have actually been built to the CAC requirements.

AIRSS defines ‘safe’ operating conditions for any ship capability (as represented by ice class) in terms of an ice numeral. This is the weighted sum of concentrations of different ice types, ranging from thin new ice to thick multi-year⁴. When operating within the Zone/Date system, a vessel is not precluded from transiting ‘unsafe’ conditions, as defined by an ice regime with a negative ice numeral, although it is discouraged from doing so. When operating under AIRSS, transiting a negative regime is prohibited.

Running the two access systems in parallel has allowed Canada to gather ice damage data for ships in both negative and positive ice regimes. This experience can be used to guide the revision of AIRSS to accommodate the introduction of the new Polar Classes.

4.2 Scientific Basis of Ice Regimes

A multi-year project examining the basis for the ice regime system⁵ conducted by the Canadian Hydraulics Centre (CHC) has developed an extensive database of safe voyages and damage events in operations under AIRSS, and used this to analyze the effectiveness of the system. This work has concluded that the existing system has functioned reasonably well; but indicates that its effectiveness could be increased (for example) by increasing the severity index of old ice for lower ice class (Types C- E) vessels, and taking more account of ice decay for higher ice class vessels. Other factors known to be important in assessing safety/risk include:

- vessel speed;
- vessel manoeuvrability;
- master/ice navigator experience;
- visibility;
- navigational equipment and availability of environmental data; and
- localized ice features (e.g., traces of glacial ice, etc).

Incorporating all of these factors into the system would increase its complexity to a point that many stakeholders have considered unmanageable. However, in adding the PC classes to AIRSS consideration should be given as to which, if any, could be taken into account.

⁴ Arctic Ice Regime Shipping System Standards, TP12259E, 1998

⁵ G.W. Timco, et. al. Scientific Basis for the Ice Regime System: Final Report TP 14274E, March 2004

5. ICEBREAKER EXPERIENCE

As part of the validation of the Ice Regime System, a number of Canadian Coast Guard icebreakers have been assigned somewhat nominal CAC designators, and requested to report on ice regimes encountered using the relevant ice multipliers to calculate overall ice numerals⁶. This data has been gathered by the ice observers on the vessels. Of interest to this current study is that all of the icebreakers from time to time are required to operate in negative ice numerals, either to fulfill escort missions or to make passages required by their operations. In certain cases, the apparent negativity of the regime is due to the vessels having been assigned relatively lower CAC capabilities than their potential, for the purposes of the data collection exercise.

The CCG captains have also reported on a subjective risk index of the damage potential while operating in different regimes, categorized as shown in Table 5.1.

Table 5.1: Definition of the Damage Potential Number

| Damage Potential Number | Description |
|-------------------------|----------------------------------|
| 1 | high potential for damage |
| 2 | potential for damage |
| 3 | not likely to damage vessel |
| 4 | highly unlikely to damage vessel |

On most of the icebreakers, ice regimes rated as having potential for damage (1 and 2) were reported quite rarely, and did not correlate very strongly with negative ice regimes. The data is too ambiguous to derive any clear trends, but does suggest that the majority of CCG icebreaker captains consider their vessels have adequate hull strength to fulfill mission requirements on (summer) Arctic deployments. This supports the analyses presented at Section 3.2.

⁶ G. Timco et. al.; Data Collection Program on Ice Regimes Onboard the CCG Icebreakers – 2002 & 2003, TP 14097

6. ICE MULTIPLIERS FOR POLAR CLASS VESSELS

6.1 Current System

The current Arctic Ice regime Shipping System (AIRSS) incorporates the ice multipliers shown in Table 6.1. The focus of this study is the top right hand corner of the table; i.e., the area in which vessels ranging from Type B (Baltic 1A) to CAC 3 are matched against potentially dangerous ice types, ranging from medium first year to multi-year.

Table 6.1: AIRSS Ice Multipliers

**Table of Ice Multipliers
for the
Arctic Ice Regime Shipping System**

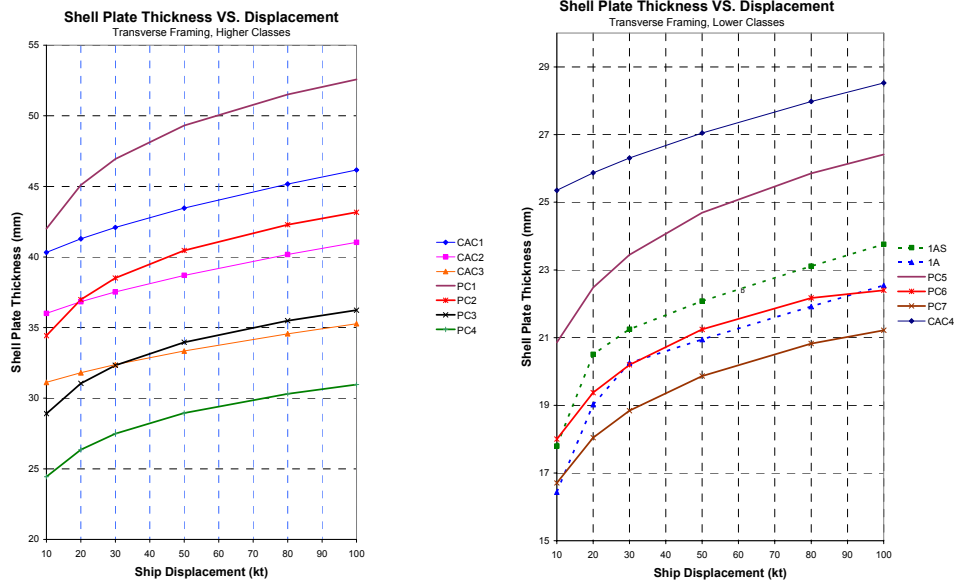
| AES / WMO Ice Codes | Ice Types | Ice Multipliers for each Ship Category | | | | | | |
|---------------------------|---|--|--------|--------|--------|--------|-------|-------|
| | | Type E | Type D | Type C | Type B | Type A | CAC 4 | CAC 3 |
| 7• or 9• | Old / Multi-Year Ice (MY) | -4 | -4 | -4 | -4 | -4 | -3 | -1 |
| 8• | Second-Year Ice (SY) | -4 | -4 | -4 | -4 | -3 | -2 | 1 |
| 6 or 4• | Thick First-Year Ice (TFY) > 120 cm | -3 | -3 | -3 | -2 | -1 | 1 | 2 |
| 1• | Medium First-Year Ice (MFY) 70-120 cm | -2 | -2 | -2 | -1 | 1 | 2 | 2 |
| 7 | Thin First-Year Ice (FY) 30-70 cm | -1 | -1 | -1 | 1 | 2 | 2 | 2 |
| 9 | Thin First-Year Ice - 2nd Stage 50-70 cm | | | | | | | |
| 8 | Thin First-Year Ice - 1st Stage 30-50 cm | -1 | -1 | 1 | 1 | 2 | 2 | 2 |
| 3 or 5 | Grey-White Ice (GW) 15-30 cm | -1 | 1 | 1 | 1 | 2 | 2 | 2 |
| 4 | Grey Ice (G) 10-15 cm | 1 | 2 | 2 | 2 | 2 | 2 | 2 |
| 2 | Nilas, Ice Rind < 10 cm | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 1 | New Ice (N) < 10 cm | " | " | " | " | " | " | " |
| | Brash (ice fragments < 2 m across) | " | " | " | " | " | " | " |
| ?Δ | Bergy Water | " | " | " | " | " | " | " |
| ???? | Open Water | " | " | " | " | " | " | " |

As noted in Section 3, the Polar Class 7 is closer in capability to a Type A than to a Type B, due to its heavier scantlings and better steel grades. This poses the challenge of adapting the AIRSS system to incorporate 5 Polar Classes, PC 3 - PC 7 within the range currently occupied by only 3 CAC: Type A, CAC 4 and CAC 3. PC 1 and 2, like CAC 1 and 2 are considered capable of unlimited operation (see Table 1).

Figures 6.1, 6.2 and 6.3 illustrate that it is not straightforward to make direct comparisons between the capabilities of Ice Classes. Factors such as displacement (shown here), hull form, and framing layout will change the relative strengthening levels. Under the CAC system, fairly high minimum scantlings are imposed, partly to reduce the risk of damage in pressured ice conditions. This boosts CAC scantling for smaller ships, especially in the midbody. Thus, a 10,000 tonne displacement CAC 4 ship has heavier scantlings than a PC 4 throughout, and approaches PC 3 in the midbody. However, by 50,000 tonnes, a PC 5 has roughly the same strength as a CAC 4 in the bow, and PC 4 exceeds CAC 4 in

the midbody (for a range of hull forms). In principle, a CAC 4 set of multipliers could be applied to PC 3, 4 or 5; depending on ship size and configuration. This would, obviously, not be workable.

Hull Family = 2, Bow Region,
s = 0.4m, a = 2m, Shear Area Ratio = 0.8



Hull Family = 2, Midbody Region,
s = 0.4m, a = 2m, Shear Area Ratio = 0.8

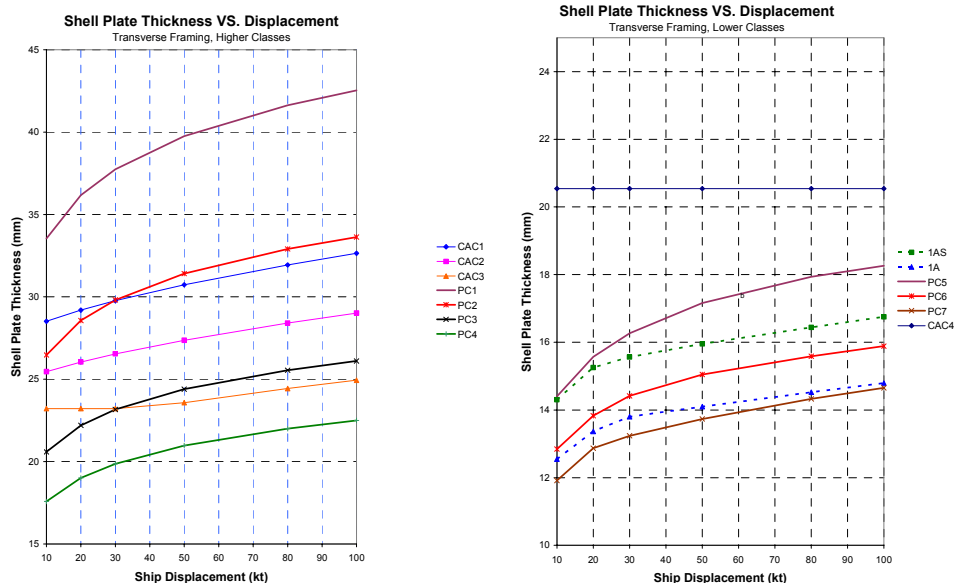
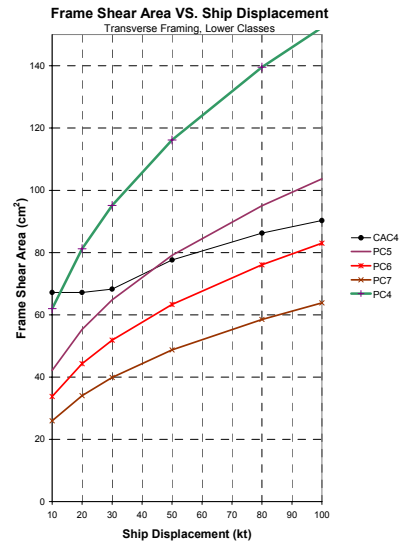
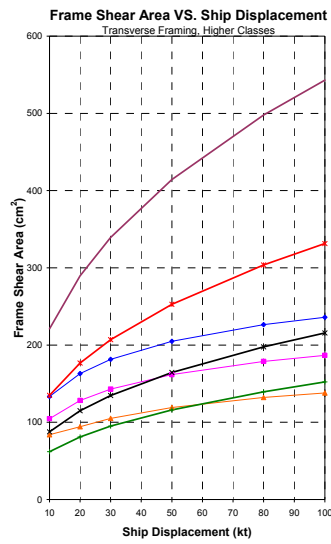


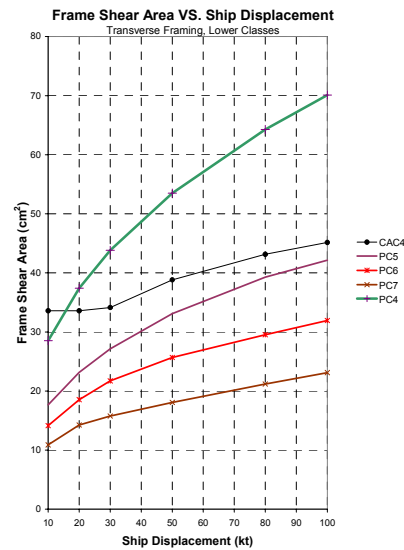
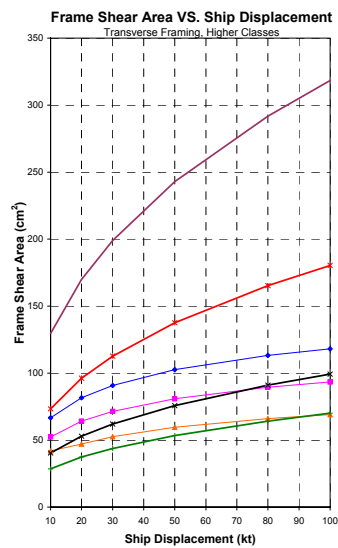
Figure 6.1: Shell Plating Comparisons: PC vs. CAC

Hull Family = 2, Bow Region,
s = 0.4m, a = 2m, Shear Area Ratio = 0.8



PURsuit_c

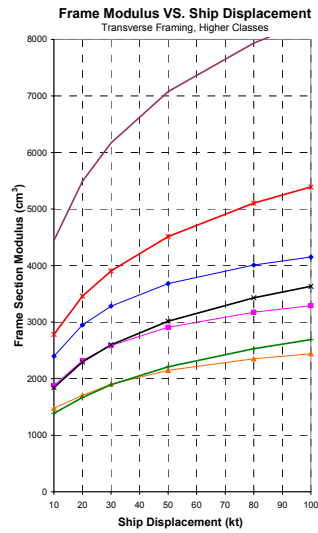
Hull Family = 2, Midbody Region,
s = 0.4m, a = 2m, Shear Area Ratio = 0.8



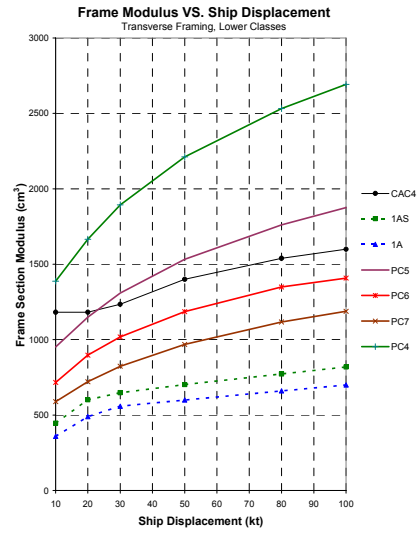
PURsuit_c

Figure 6.2: Frame Shear Area Comparisons: PC vs. CAC

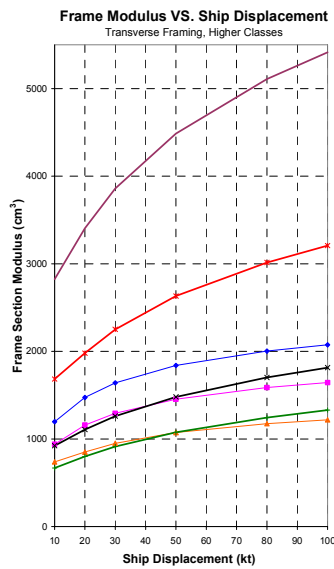
Hull Family = 2, Bow Region,
 $s = 0.4\text{m}$, $a = 2\text{m}$, Shear Area Ratio = 0.8



PURsuit_c



Hull Family = 2, Midbody Region,
 $s = 0.4\text{m}$, $a = 2\text{m}$, Shear Area Ratio = 0.8



PURsuit_c

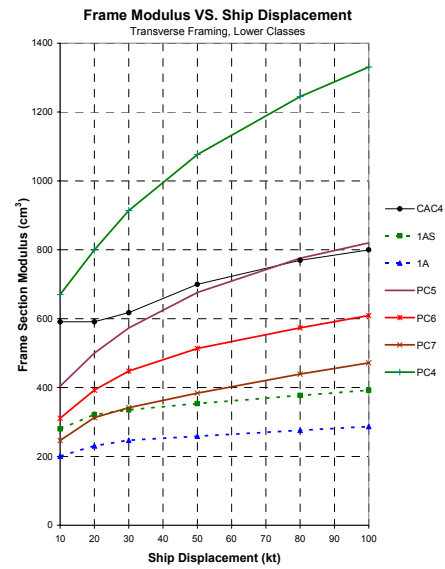


Figure 6.3: Frame Modulus Comparisons: PC vs. CAC

It is necessary to bear in mind that no vessels have actually been built to the CAC requirements. Only a few existing vessels have been assigned a CAC designation (or similar AIRSS multipliers), and generally on pragmatic rather than scientific grounds. Therefore, in practice it can be considered that the upper end of the AIRSS table has not been validated. It could be removed entirely without impacts on any current vessel or shipping operation, with the minor exception of the M.V. Arctic.

6.2 Potential Approaches

Several quite different approaches to incorporating Polar Classes within AIRSS can be envisaged. At one end of the spectrum would be an ‘incremental’ solution, in which PC 3-7 would be mapped onto the AIRSS domain of Type B to CAC 3. This could be done in a reasonably logical manner as shown in Table 6.2. Type B retains its current multipliers. PC 3 is given a capability marginally above CAC 3 by making the multiplier for multi-year ice 0 rather than -1. This recognizes that vessels with this level of capability are highly likely to have to transit multi-year ice from time to time, and are capable of doing so safely, provided that reasonable caution is observed. The CCG icebreaker experience summarized above supports this argument. The other ice classes are inserted into the table in stepwise fashion, as in the current system. The addition of the 0 multiplier reduces the size of capability jumps and permits the insertion of the extra Polar Classes. Under this version of the system; decay, ridging and other adjustments to the basic numeral would be applied as is done now.

Table 6.2: Ice Multipliers for Polar Classes (Option 1)

| AES / WMO Ice Codes | Ice Types | | Ship Classes | | | | | |
|------------------------------|--------------------------------|--------------|--------------|--------------------|---------|---------|------|------|
| | | | Type B | Type A /PC 7 | PC 6 | PC 5 | PC 4 | PC 3 |
| 7• or 9• | Old / Multi-Year Ice (MY) | | -4 | -4 | -3 | -2 | -1 | 0 |
| 8• | Second-Year Ice (SY) | | -4 | -3 | -2 | -1 | 0 | 1 |
| 6 or 4• | Thick First-Year Ice (TFY) | > 120cm | -2 | -1 | 0 | 1 | 2 | 2 |
| 1• | Medium First-Year Ice (MFY) | 70-120 cm | -1 | 0 | 1 | 2 | 2 | 2 |
| 7 | Thin First-Year Ice (FY) | 30-70 cm | 1 | 2 | 2 | 2 | 2 | 2 |

A more comprehensive approach for operation under AIRSS would be to split all vessels into 'seasonal' and 'year round' categories. The seasonal ships include all Types, and PCs 6 and 7. These ships would be required to operate using the ice numeral go/no-go decision criterion more or less as at present (or following the relevant columns of Table 6.2). However, for the PC 5 and above the numerals would become indicative rather than prescriptive; i.e., they would permit operators to quantify risk and operate accordingly.

All vessels built to the higher polar classes will be very specialized ships, designed for specific polar operational requirements. They will have double hull construction in way of any pollutants, good quality steel in all ice belt areas, and extensive navigational equipment (including voyage data recorders). They are also likely to be crewed by highly experienced deck officers and ice navigators. They are required to have operating and training manuals that cover procedures for adjusting operations in accordance with the ice conditions they expect to encounter. For all of these reasons, it is highly improbable that they will be operated in heavy (multi-year) ice conditions at speeds that could incur extensive structural damage, and thus pose safety or environmental dangers. The highest risk of major damage will be in light ice or open water transits where low concentrations of old or glacial ice are present, and such scenarios are not covered by (or exclusive to) the AIRSS system.

7. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This project has reviewed some of the differences between the IMO/IACS Polar Class systems and the systems currently applied in Canadian Arctic waters. Existing ships have been matched against PC (structural) requirements in fairly general terms – any existing ship has to be tested in detail against a new system of requirements to confirm its actual degree of compliance or of relative capability. On average, a new PC 7 vessel will have safe Arctic operability limits similar to those of a Type A (Baltic 1AS).

It would be quite simple to integrate the Polar Classes into the existing AIRSS system of ice multipliers and ice numerals, but this is not necessarily the best approach to adopt. Higher polar class vessels should not be considered ‘unsafe at any speed’ when operating in multi-year ice. For safety and pollution prevention, it is likely to be acceptable to place reliance on self-regulation of operating procedures, especially if these have been reviewed and approved in advance by a competent authority.

The following steps are recommended to strengthen the basis for incorporating the lower Polar Classes into AIRSS, and to explore the ‘comprehensive’ option for treatment of the higher polar classes:

1. revisit the damage and any relevant scantlings data for Type A and B vessels to confirm the evaluation of relative polar class safety levels;
2. review the requirements for training and operational documentation contained in the IMO Guidelines, other relevant IMO documentation, and Canadian regulations and standards to assess the need for additional guidance to meet Canadian safety and pollution prevention expectations;
3. continue the collection of good quality Arctic voyage data on both commercial vessels and icebreakers; and
4. maintain and expand the CHC database as a basis for further analyses.

Outside the scope of this study, but as a more general observation, it is recommended that the introduction of the Polar Classes under AIRSS should be used to catalyze a broader reform of the regulations and standards supporting the Arctic Waters Pollution Prevention Act. The current system is complex and confusing. Adding a further set of ‘equivalent standards’ for the construction and operation of Polar Classes will worsen this situation.